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“What is the benefit of that?” Mathematics Teachers’ Motives in Discarding Digital Technology in their Teaching

Marie Utterberg
University of Gothenburg

Johan Lundin
University of Gothenburg

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Marie Utterberg and Johan Lundin

Department of Applied IT, University of Gothenburg, Sweden

Abstract. In many countries, digital tools in mathematics education are promoted in policy. Despite this, contemporary research shows that mathematics teachers use digital tools in education less frequently as compared to teachers in other subject areas. There is a lack of research on teachers’ reasons for discarding digital tools that has a specific focus on mathematics education. In this study, we have interviewed teachers who define themselves as discarding digital tools in their teaching and described how alternative activities emerge when those teachers are engaged in mathematical learning. Cultural-historical activity theory and a thematic analysis revealed three conditions that are important for teachers’ activities: policy, teacher practices, and digital tools.

Keywords: Mathematics education, teachers, digital tools, cultural-historical activity theory, need, motive, thematic analysis.

1 Introduction

The use of digital tools in mathematics education is understood as a prerequisite for achieving the objectives of mathematical literacy, key competencies and lifelong learning stated by, for example, the European Union [1], OECD [2] and the National Council of Teachers of Mathematics (NCTM) [3]. Policy has increasingly focused on the use of technology in teaching and learning mathematics [4]. In recent years, several European countries have revised their mathematics curricula to provide a stronger focus on competencies and skills, interdisciplinary connections, IT strategies, and the application of mathematics in daily life [5]. Programming is often argued to have a connection to mathematics and has become part of the mathematics curricula in many countries [6, 7, 8, 9], emphasizing that policymakers understand mathematics as a subject that has close relations to digital tools, as well as to how these tools are constructed.

Meanwhile, research shows that mathematics teachers use digital tools in education less frequently as compared to teachers in many other subject areas [10, 11]. The successful integration of technology in mathematics education at a large-scale level is a major issue [12]. In a study by Bretscher, mathematics teachers from 50 schools took part in a survey about the use of digital tools. This survey revealed that digital tools, despite policies intended to support their use in problem solving and abstract thinking, are rarely used in mathematics classrooms. Thus, quantitative and qualitative gaps have been identified between policy expectations and reality [13]. Zuber and Anderson suggest that "there may be specific aspects of mathematics teaching that influence the response to technology innovation" [14]. Teachers play a key role in implementing digital tools, but learning to teach with technology remains demanding for many teachers [15]. For successful implementation, teacher skills in digital tools and knowledge about how they can be used to support teaching and learning are necessary [16] but not sufficient. Teacher beliefs about teaching and learning and how these beliefs are intertwined with meaningful technology use are crucial factors as well [17, 18]. There has been an increased interest in research about teachers' relationships to digital tools in the classroom, and more knowledge about teachers' underlying reasons for adopting digital tools would be beneficial [19].

Understanding and predicting the uptake of digital technologies in various settings is a central theme in research on the digitalization of work and life. Theoretical frameworks such as the Technology Acceptance Model (TAM) [20] and the Unified Theory of Acceptance and Use of Technology model (UTAUT) [21] have attempted to address these issues, primarily with a factorial approach. Concerning teachers in particular, several conditions have been suggested as impacting the uptake of digital tools, such as professional development, support, and access to resources and the Internet [22, 23]. However, there are few studies explaining which factors can account for differences between subjects in terms of their uptake of digital technologies in education. In a situated social practice, meaning, identity, and norms are locally negotiated and sustained [24]. This indicates that in addition to teacher competence with and attitudes toward digital tools, the practical work of making these new tools useful in the everyday practice of teaching is central.

In this paper, we take a somewhat different approach from prior research on the adoption of technology in general and on teachers' adoption of technology in particular. Rather than examining larger groups of teachers and identifying factors affecting the high-level and low-level adoption of technology, we examine mathematics teachers who define themselves as reluctant regarding or non-adopters of the use of technology in their teaching. The focus is on mathematics teachers' reasons for not engaging more fully with digital tools in their teaching. The differences in adoption described above lead us to believe that there are specific aspects of mathematics education that drive the gap between high expectations and low adoption. Rather than focusing on analytically derived conditions based on a large body of respondents, we want to understand what teachers themselves define as acceptable reasons for discarding digital tools in their teaching, despite pressure from policy and management. Foundational concepts from cultural-historical activity theory are used to discern crucial factors. The research question is as follows: What contradictions are revealed by teachers who reason about their motives in discarding digital technology?

2 Related Research

Analytically, we approach the classroom as an activity system in which teachers' instructions and their views on teaching and learning are situated in a culture of participation [25]. Teachers' instructional activities are not merely situated in the immediate material teaching setting but also within their participation in a practice with a history that establishes how mathematics is taught and learned. Teachers engage in actions to carry out this activity, and these actions are directed towards goals, which they conceive of as central [26]. Their actions are evoked by a motive and directed towards a goal. Just as motive is related to activity, so purpose is related to action [27]. The teacher's narratives in this study allow us to investigate the motives and goals of mathematics teachers' practice. The teacher narratives are also relevant to our analysis because they can provide an understanding of their pedagogical beliefs [28], as well as the subject culture.

The concept of motive is essential in our research. Teachers' activities arise from a motive. The connection between motivation and the possibilities for action is developed based on needs, which affects the impact of the subject's behaviour [26]. A motive meets a certain need on the part of the subject and hence becomes an object. Importantly, an object can be *constructed*. That is, it can be formulated and defined, for example, by policy. The object is then explicitly defined. The effort to *instantiate* an object refers to actually realizing the object and reaching an outcome. However, an object, together with its motive, is negotiated within social processes in which many interests are involved [29].

A central concept in our analysis is the notion of disruptions. A disruption in the activity system may occur due to contradictions [30], as will be shown in this study. Primary contradictions respond to conflicts in which individuals face inner doubts, leading to a state of uncertainty, a need state [31]. A need state that lasts for a long period gives rise to stagnation and alternative activities. Subjects' choices are not generating new activities; rather, the subject will be aware of only old and less-advanced activities [30]. In order to develop activities, the need state must be reformulated and transformed into a double bind [30, 32]. Double binds are rooted in secondary contradictions that appear between the components of an activity. A double bind is when a subject must do something to resolve an experienced problem but, at the same time, faces impossible alternatives, meaning that a solution would require practical and collective action [33].

3 Method

The research described in this paper considers teachers' daily lives in a complex practice affected by disruptions. A case study is appropriate in these circumstances because it provides an in-depth understanding of the context and its related conditions [34]. To conduct this study, we needed to identify teachers who were willing to both define themselves as discarding digital tools in their teaching, as well as be interviewed about this position. Through the first author's contacts, ten Swedish mathematics teachers who met the first criterion were identified. Those ten teachers had passed a teaching exam in mathematics and had several years of experience. One additional selection criterion was that they should be practicing in schools at which there was available technology to discard; i.e., they should not teach at schools without digital technology for the students to use. Thus, all teachers taught classes in which their students had access to computers or iPads. Experience with teaching practices allowed the first author to choose teachers that were positioned as skilled teachers in their local practice but more-or-less openly discard the use of digital tools. We made this choice because there are some teachers who are less interested in developing their teaching more in general. The teachers selected for this study are engaged in professional development to increase the quality of mathematics instruction. This allows us to assume that they are interested in mathematics teachers' professional development generally, as well as their own professional development specifically. Due to this, we can assume that their engagement in professional development positively affects their teaching in their own mathematics classrooms. Every teacher was asked for his or her consent to take part in this study and informed that all answers would be anonymized in presentations of the material.

Table 1. Information about the teachers

Teacher	Years of Teaching	Year Group
1	20	Year 9 (age 16)
2	9	Year 7-9 (ages 13-15)
3	20	Year 7-9 (ages 13-15)
4	18	Year 9 (age16)
5	9	Year 6-9 (ages 12-15)
6	18	Year 4-6 (ages 10-12)
7	20	Year 4-6 (ages 10-12)
8	15	Year 7-9 (ages 13-15)
9	17	Year 7-9 (ages 13-15)
10	30	Year 1-5 (ages 7-11)

One suitable tool for identifying a motive is interviews [35]. Interviews are also a particularly suitable method for describing why and how things change [36]. Additionally, they are suitable because they can explain why things do not change as may be expected. We adopted an interview guide approach [34], and topics identified from previous research were covered with open-ended questions, allowing the informants to elaborate on their answers. The topics included are as follows: informants' demographic information, learning and teaching mathematics, the implementation of digital tools in the classroom, digital tools in the local school context, and debates of technology and learning in society. The participants were individually interviewed from February to April 2017, and each interview lasted for one hour on average. The responses were audio recorded and transcribed verbatim.

The responses from the interviewees were analysed using a deductive thematic analysis model described by Braun and Clarke [37]. The transcripts were repeatedly and carefully read, and an initial coding was conducted. The coding data were organized into themes, reviewed, refined, and subsequently defined. The analysis is grounded in the empirical data, as well as in cultural-historical activity theory. The analysis resulted in two themes, which are presented in the next section.

4 Results

Our analysis resulted in two themes: teachers' understanding of learning mathematics, which reveal their goals and actions, and teachers' motives as influenced by their needs (or lack of needs).

4.1 Teachers' understanding of learning mathematics

We identified three subthemes that correspond to teachers' goals regarding students' mathematical learning: verbal mathematical communication, written mathematical communication, and finally, students' use of various senses in their mathematical learning.

Verbal mathematical communication: The teachers emphasize communication and view mathematics as a language. "Have to talk a lot. It happens in the meeting between you and me. /…/ I believe very much in the conversation. /…/ Mathematics is a language that I also need to understand" – (Teacher 5). The teachers stress that learning mathematics is dependent on verbal communication when discussing various mathematical strategies and solutions. Students learn by listening to others, as well as through explaining their own mathematical thinking. In addition, having students explain their reasoning allows the teacher to become aware of students' misunderstandings. Teachers stress discussions in the classroom and the importance of students developing their mathematical communication skills. The importance of communication, as a tool for both the teacher and the students, was expressed as follows:

> *Firstly, it is that you get to know how they think, and then, it is easier to help them. And secondly, it is that, to be able to turn and twist with someone else. Why do you say that? Yes, but I thought in that way. But if you think like this, what will happen then? Or, I thought in this way, but we came to the right answer anyway*. – (Teacher 2)

The teachers also find that the use of digital tools contradict their own pedagogical ideas and limit activities in the classroom. One teacher expressed that she experiences that their use limits her chances to interact with her students regarding their mathematical activities. "And because you were not always next to the student, so you could say: Well, now you clicked there. How did you think then? Can you explain to me why it became in that way? /…/ How can I then get hold of the learning?" – (Teacher 6)

Written mathematical communication: For the interviewed teachers, written mathematical solutions are central to mathematical learning:

> *…write algorithms, that the solution is structured, doing their own solutions. Because then you learn, at least when you get into more*

> *advanced tasks. If you do an error, you have a solution that is structured. Then, you can see what went wrong.* – (Teacher 5)

The idea that written mathematics, in the form of both words and pictures, is important for student learning was also mentioned by many teachers. They emphasized that students' solutions should be structured and clear, as well as being written in mathematical language and preferably including drawings. This view about handwritten mathematics influences the uptake of digital tools because those who hold this view do not support the idea of students merely touching a screen or typing in numbers.

> *I do not want them to use interactive material, where you touch the answer or write the numbers with the keyboard. Because I think that they need to use pen and paper. /…/ They need to be able to make a good solution, thus a solution that is understandable*. – (Teacher 2)

One teacher contrasted his idea about the importance of communicating mathematics in writing with his experiences of students using digital tools.

> *They worked individually with their own tasks and wrote the answer on the computer. I also found that more students probably got away easier, thus they did not get as much done as before. And you lose this* (a written solution)*, you are thinking and write a scrap paper and then write the solution on the computer. Then, you do not have a written solution, and if you are going to cover the curriculum, one part is communication.* – (Teacher 5)

Mathematical representations and several senses: The teachers reported that students should use several senses because they benefit from perceiving mathematics as a sensory experience. Some teachers emphasized physical tools as a way to increase students' understanding of abstract mathematics via a sensory-motor, or "hands-on," approach.

> *It will be, like, an engaged lesson. I could have had a lecture about the topic, but this makes the students remember the lesson. /…/ It will be linked to a bodily experience. I have done something with my hands. I have sorted.* – (Teacher 7)

Teachers say seeing a physical representation and being able to squeeze and feel it offer a great deal to students. This representation can be a paper box representing one cubic meter, classical educational material showing a certain volume, or a protractor. Students understand concepts more completely when they use physical tools than when they, for example, simply look at geometric objects on a computer. Teachers also describe mathematical problem solving outside the classroom using the physical environment or inside the classroom by incorporating reality in the form of, for example, video-clips. The idea is that this will drive students toward thoughts and reflections that are not supported by the pre-arranged tasks usually found in the textbook.

Summary: When the teachers talked about the actions they took to accomplish what they define as good teaching, they described various ways in which they work related to their view of learning. The textbook was mentioned only sporadically as a base. The teachers emphasized students' conceptual understanding and how they plan their instruction to deepen student understanding. This is an instantiating object, which means that the object is an intended outcome and teachers attempt to achieve this outcome through actions, which are based on goals. Teachers' goals are to deepen students' mathematical understanding of appropriate mathematical concepts. Their actions are providing instruction that supports students' conceptual understanding through the use of physical tools that involve several senses and meaning making, as well as instruction that supports students' verbal and written mathematical communication in order to highlight strategies, methods and potential errors and thus enhance learning. The teachers' experience is that digital tools interfere with their goals and the actions they take to achieve those goals.

4.2 Teachers' motives are influenced by need (or a lack of need)

Even though there are changes in policy and direction, the teachers reported a lack of need concerning the use of digital tools. They propose that teaching in what they define as a traditional way is much more efficient and that their efforts in using technology do not lead to students achieving better results.

> *I want to use the tool that I think gives the best effect, best results actually. That's my standpoint, and not just implements IT because now we'll have IT in the classroom. What is the benefit of that? /.../ I have probably said it ten times now, but it must provide some form of gain / ... / Thus, everything takes a lot longer, and it's more difficult than you think. I often noticed, that what you got out of it did not became better than when you did it traditionally.* – (Teacher 5)

In the following utterance, a teacher emphasizes the lack of need for digital tools in mathematics and provides an example of how digital tools are used more commonly in other subject areas.

> *I think it might be that we just do not see the need for IT in mathematics. We talk a lot more about IT in Swedish* (first language learning)*, civics, and the natural sciences. We use it a lot, like this, to search for information, when we are going to make video clips and how to handle that. We will, maybe, present and store things. Then, we talk a lot more about how we are using IT and how we will relate to it, than in mathematics.* – (Teacher 7)

Teachers lack a motive to use digital tools in teaching. They do not experience that it improves mathematics instruction or student learning. Not only are the new tools perceived as having the same or even less impact on student learning, they are also viewed as more time-consuming.

> *Well, you have to keep working all the time and give the children what they need. So, I don't think that much about the digital tools anymore/.../ I can't see what it could bring into math. /.../ I don't think the digital tools will enhance the mathematical skills for the Swedish students.* – (Teacher 3)

One teacher trained in special educational needs teaches a small group of students with difficulties in learning mathematics. She explained that her motivation was not related to using digital tools. Rather, she stressed her personal relationships with students, which she described as one of the reasons for using iPad applications to a very small extent. Her relationships with her students are understood as crucial for their self-confidence and motivation, introducing other aspects of teaching beyond the development of content knowledge. This teacher believes that iPads give rise to individual work, meaning that such relationships will suffer.

> *The motivation I have in my work, and we have used iPads, applications and so on but they create no Hallelujah moments. Thus, it* (my motivation) *is about completely different things. Hallelujah moments are personal meetings when students begin to trust me and we can start working.* – (Teacher 10)

Some teachers talked about the overly strong belief that digital tools will solve all problems involved in learning mathematics. In addition to this transformative and somewhat techno-deterministic understanding, they also experience a perspective purveyed by management and policy that emphasizes the technology per se, rather than the teachers' actual teaching activities in which such technology may be used. These teachers point to an implicit idea that if digital tools are simply used in the classroom, everything will be fine.

> *Everything is fine if only IT is involved. That makes me so tired. /.../ Just because IT is involved, everything isn´t ok just because you say so. No, that's my opinion. It has to be a good thing, something that can contribute. It doesn't solve everything for students having difficulties in learning math. Just because we have one iPad for every student, it doesn't mean that everything is great. That's not my opinion, anyway. I can feel that all this is overrated, and maybe, it aims to high.* – (Teacher 1)

When mathematics teachers use digital tools in their classrooms, they relate this to learning mathematical procedures and rules.

We have mostly worked with the computers for learning rules and procedures, multiplication, division, the clock. /.../ They (iPads) *are used a lot for learning rules and because they are easily accessible. If they* (students) *have difficulties learning, for example, the order of operations, then I know which app to use for training those skills.* – (Teacher 7)

Teachers also stress that with digital tools, students are able to perform many tasks, without teachers having to engage in correcting these tasks. "For those students who just practice rules and methods, it is fantastic that it is self-correcting. They receive immediate feedback" – (Teacher 8). Students can work on their own with most applications, and this is useful when the teacher does not have time to help. One teacher saw the possibility of using technology as a way to handle a class with many students. His students have software with tasks, that suggests mathematical solutions and corrects students' answers.

Because then you actually get an answer, that is, if you do it right, and you get suggestions for solutions as well. So, then, you learn some from it. It's very good because then, they can actually get some help when I'm sitting with someone else. – (Teacher 5)

Thus, the teachers associated the use of technology with having the chance to individualize teaching in school and also at home, where the same applications are made available to students. Another advantage expressed was the use of instructional video clips, allowing for variation and students' individual learning. When using digital tools to support students' work at home, teachers use the Learning Management System that is available at school. Video clips from YouTube, links to the Internet, tips regarding various apps, and lesson plans are published to facilitate students' individual work. Moreover, one reason teachers mentioned for using technology was that classroom work became a bit more easy-going. "It may get a bit joyful, and that is good*."* – (Teacher 10)

Summary: From the data included within this theme, we find that the object of using digital tools for teaching and learning has been constructed by policy. Teachers attempt to realize this object, but this leads to a conflict of motives. Teachers' motives in instantiating the object and thus achieving the outcome that students learn mathematics are not aligned with the constructed object. Thus, teachers lack a need and, subsequently, a motive. This conflict becomes visible in that the teachers emphasized conceptual learning but used digital tools mostly for root learning or generic use, for example, in the form of video clips. This conflict pushes the object toward an alternative activity: the complementary use of digital tools.

5 Discussion

The results of this study reveal three important conditions for understanding teachers' activities: policy, teacher practice, and digital tools, as represented in Figure 1.

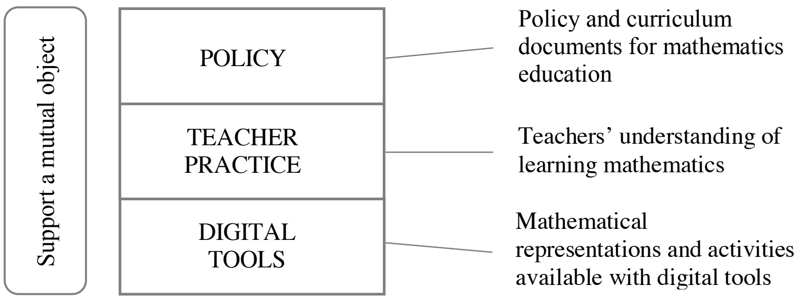

Figure 1: A mutual object is a prerequisite for transformation into an activity.

The mathematics teachers who appear in this study teach in a way that is perceived as good among their peers. When the teachers described their views of teaching and learning mathematics, they were typically in line with the principles stressed by the NCTM as leading to meaningful learning [3]. In brief, their teaching is based on a belief that communication, both oral and written, and mathematical representations are a prerequisite for learning and discovering students' potential mathematical misconceptions. What seems problematic for the teachers is understanding how digital tools can support them in their convictions regarding how mathematics education should be conducted. Their experience is that digital tools contribute to procedural learning, which they do not view as a sufficiently way to learn mathematics. They argue that with technology, students will gain a mathematical understanding that can be achieved with traditional instruction, only less efficiently. This is a primary contradiction experienced by the teachers. The teachers are aware of policies and debates in society suggesting that technical development and digitalization should impact education and that students should have the chance to learn mathematics using digital tools. However, they do not perceive any substantial benefits of using digital tools in their classrooms. There is no object to meet the need, and therefore, there is no motive to do so. A motive is elicited by the external environment, but the presently available technology is unsuitable because the teachers do not find that the technology's affordances correspond to their view of learning mathematics. This gives rise to a disruption in the system of activity. A need evokes an activity to satisfy that need, but the resources available during the activity cannot satisfy the new need, and thus, a need state occur [31]. A state of uncertainty emerges. One indication of this uncertainty in the data is one teacher asking whether there was any research showing that students would learn more mathematics with digital tools: "I want to know if you learn better in the one way or the other" – (Teacher 4).

Government and educational authorities promote an educational practice in which technology supports mathematical problem solving and conceptual understanding [2], but teachers experience that the technology supports individual and procedural learning. Changes in the curriculum introduced by the government and education authorities have reduced teachers' instructional freedom regarding digital tools. This is a secondary contradiction between components in the activity, leading to a double bind [30]. One example on this appears when one teacher stresses the importance of

IT because everything in the society is digitalized but, at the same time, questions what to do with the digital tools in school: “In that case, what is expected of us? What is the school supposed to do?” – (Teacher 9). The teacher moves from an *I* to a collective *us* in a rhetorical question, indicating helplessness. Such a change can be understood as a manifestation of a double bind [33].

For government and education authorities, the object of the motive is that students will learn mathematics via a digitalised education. For example, NCTM suggests that technology, when used appropriately, supports effective and meaningful learning by helping teachers and students visualise and concretise mathematics abstractions [3]. The object that motivates the teachers is that their students will learn mathematics, and they emphasized a pedagogy based on communication and various representations, which the teachers find difficult to achieve using digital tools. The government promotes one activity, but the teachers participate in another kind of activity, which makes the objects of the motive different. The teachers have not become aligned with the motive emphasised in policy and curriculum documents, but in some way, they have accepted it. This acceptance of the motive appears in the alternative activity being developed, giving rise to teachers’ actions regarding the use of digital tools in a limited area. Teachers attempt to plan their teaching in such a way that the use of digital tools will not come into conflict with their beliefs about learning. Consequently, they sometimes use digital tools and to help students in performing routine tasks that support root learning or use them generically. As pointed out by Moreno-Armella and Santos-Trigo, “No artefact is epistemologically neutral” [38]. This could explain some of the results from studies focusing on what mathematics teachers use technology for [13, 11].

Even though the teachers perceived the need state individually, the solution must be a collective formation of new thoughts [40]. Teachers’ uptake of digital tools change the conditions of teaching and learning and challenge the traditional classroom culture. As Sannino describes it, “actions with innovative goals are demanding because the individual has to build up continuity between the new and what already exists” [41]. The teachers’ activity responds to a motive and its object, which differs from the externally expected object, or the created object. Furthermore, the distance between teachers’ perceived benefits and the advantages actually provided seems to be considerable. Hence, the intended and implemented curricula [39] do not coincide. Teachers discard technology regardless of national expectations. Consequently, to ensure the use of technology in mathematics education policy, teachers’ views of learning mathematics and the opportunities involved in using digital tools in classrooms must coincide and support a mutual object.

References

1. Tapio, S.: Implementation of Education and Training 2010, Work Programmed-Key Competences for Lifelong Learning. A European Reference Framework (2004)
2. PISA 2015 Assessment and Analytical Framework: Science, Reading, Mathematic and Financial Literacy, PISA, OECD Publishing, Paris (2016)
3. National Council of Teachers of Mathematics (NCTM). Principles to Action: Ensuring Mathematical Success for All. Reston, VA: NCTM (2014)

4. Trouche, L., Drijvers, P., Gueudet, G., Sacristan, A. I.: Technology-Driven Development and Policy Implications for Mathematics Education. In Clements, M. A., Bishop, A. J., Keitel, C., Kilpatrick, J., Leung, F. K. S. (eds.) Third International Handbook of Mathematics Education. pp. 753--789. Springer, New York (2013)
5. EACEA.: Mathematics Education in Europe: Common Challenges and National Policies (2011)
6. Swedish National Agency for Education.: Curriculum for the Compulsory School 2011. Fritzes, Stockholm (2011) https://www.skolverket.se/om-skolverket/publikationer/visa-enskildpublikation?_xurl_=http%3A%2F%2Fwww5.skolverket.se%2Fwtpub%2Fws%2Fskolbok%2Fwpubext%2Ftrycksak%2FRecord%3Fk%3D2575
7. Finnish National Board of Education: Core Curriculum for Basic Education. National Board of Education, Helsinki (2014) http://www.oph.fi/lp2016/grunderna_for_laroplanen
8. Gadanidis, G.: Computer Coding in the K-8 Mathematics Curriculum? What works? Research into Practice. Research monograph # 69 (2017), http://www.edu.gov.on.ca/eng/literacynumeracy/inspire/research/Computer_Coding_K8_en.pdf
9. Papert, S.: Mindstorms: Children, Computers, and Powerful Ideas. BasicBooks, New York (1993)
10. Howard, S. K., Chan, A., Mozejko, A., Caputi, P.: Technology Practices: Confirmatory Factor Analysis and Exploration of Teachers' Technology Integration in Subject Areas. Computers & Education. 90, 24--35 (2015)
11. Blackley, S., Walker, R.: One-to-One Laptop Programs: Is Transformation Occurring in Mathematics Teaching. Issues in Educational Research. *25*(2), 99--117(2015)
12. Artigue, M.: The Future of Teaching and Learning with Digital Technologies. In: Hoyles, C., Lagrange, J. B. (eds.) Mathematics Education and Technology –Rethinking the Terrain. pp. 463--475. Springer, New York (2010)
13. Bretscher, N.: Exploring the Quantitative and Qualitative Gap Between Expectation and Implementation: A Survey of English Mathematics Teachers' Uses of ICT. In: Sinclair, N., Clark-Wilson, A., Robutti, O. (eds.) The Mathematics Teacher in the Digital Era: An International Perspective on Technology Focused Professional Development. pp. 43--70. Springer, Netherlands (2014)
14. Zuber, E. N., Anderson, J.: The Initial Response of Secondary Mathematics Teachers to a One-to-One Laptop Program. Mathematics Education Research Journal. *25*(2), 279--298 (2013)
15. Zbiek, R. M., Hollebrands, K.: A Research-Informed View of the Process of Incorporating Mathematics Technology into Classroom Practice by In-Service and Prospective Teachers. In: Heid, M. K., Blume, G. W. (eds.) Research on Technology and the Teaching and Learning of Mathematics: Vol 1. Research Syntheses. pp. 287--344. Information Age Publishing, Charlotte, NC (2008)
16. Bretscher, N: Beyond a Positive Stance: Integrating Technology is Demanding on Teachers' Mathematical Knowledge for Teaching. In: Proceedings of the Tenth Congress of the European Society for Research in Mathematics Education. Dublin, Ireland (2017)
17. Prestridge, S.: Examining the Shaping of Teachers' Pedagogical Orientation for the Use of Technology. Technology, Pedagogy and Education. 26(4), 367--381 (2017)
18. Tondeur, J., van Braak, J., Ertmer, P. A., Ottenbreit-Leftwich, A.: Understanding the Relationship Between Teachers' Pedagogical Beliefs and Technology Use in Education: A Systematic Review of Qualitative Evidence. Educational Technology, Research and Development. 65(3), 555--575 (2017)
19. Drijvers, P., Monaghan, J., Thomas, M., Trouche, L.: Use of Technology in Secondary Mathematics. Final Report for the International Baccalaureate. (2015) http://www.ibo.org/globalassets/publications/ibresearch/technologyindpmathematicsfinalreport.pdf.

20. Davis, F. D.: Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. MIS Quarterly. 319--340 (1989)
21. Venkatesh, V., Morris, M. G., Davis, G. B, Davis, F. D.: User Acceptance of Information Technology: Toward a Unified View. MIS Quarterly. 425--478 (2003)
22. Mumtaz, S.: Factors Affecting Teachers' Use of Information and Communications Technology: A Review of the Literature. Journal of Information Technology for Teacher Education. 9(3), 319--342 (2000)
23. Hew, K. F., Brush, T.: Integrating Technology into K-12 Teaching and Learning: Current Knowledge Gaps and Recommendations for Future Research. Education Technology Research and Development. 55(3), 223--252 (2007)
24. Wenger, E.: Communities of Practice: Learning, Meaning, and Identity. University Press, Cambridge (1998)
25. Cobb, P.: The Importance of a Situated View of Learning to the Design of Research and Instruction. In: Boaler, J. (ed.) Multiple Perspectives on Mathematics Teaching and Learning. International Perspectives on Mathematics Education. pp. 45--82. Ablex Publishing, USA (2000)
26. Roth, W. M., Lee, Y., J.: "Vygotsky's Neglected Legacy": Cultural-Historical Activity Theory. Review of Educational Research. 77(2), 186--232 (2007)
27. Leontév, A. N.: Activity, Consciousness and Personality. Prentice Hall Englewood Cliffs, NJ (1978)
28. Ertmer, P. A.: Teacher Pedagogical Beliefs: The Final Frontier in Our Quest for Technology Integration? Educational Technology Research and Development. 53(4), 25--39 (2005)
29. Kaptelinin, V., Nardi, B. A.: Acting with Technology. Activity Theory and Interaction Design. MIT Press (2006)
30. Engeström, Y.: Learning by Expanding. Cambridge University Press (2014)
31. Bratus, B. S., Lishin, O. V.: Laws of the Development of Activity and Problems in the Psychological and Psychological Shaping of Personality. Soviet Psychology. 21(3), 38--50 (1983)
32. Bateson, G., Jackson, D. D., Haley, J. D., Weakland, J.: Toward a Theory of Schizophrenia. Behavioral Science. Vol. 1, 251—264. (1956)
33. Engeström, Y., Sannino, A.: Discursive Manifestations of Contradictions in Organizational Change Efforts: A Methodological Framework. Journal of Organizational Change Management. 24(3), 368--387 (2011)
34. Cohen, L., Manion, L., Morrison, K.: Research Methods in Education. Routledge (2011)
35. Hardman, J.: An Exploratory Case Study of Computer Use in a Primary School Mathematics Classroom: New Technology, New Pedagogy? Perspectives in Education. 23(4), 1--13 (2005)
36. Rubin, H. J., Rubin, I. S.: Qualitative interviewing: The Art of Hearing Data. SAGE (2011)
37. Braun, V., Clarke, V.: Using Thematic Analysis in Psychology. Qualitative Research in Psychology. 3(2), 77--101.
38. Moreno-Armella, L., Santos-Trigo, M.: The Use of Digital Technology in Mathematical Practices. Reconciling Traditional and Emerging Approaches. In: English, L.D., Kirshner, D. (eds.) Handbook of International Research in Mathematics Education. pp. 595--616. Routledge, New York (2016)
39. Mullis, I. V., Martin, M. O., Ruddock, G. J., O'Sullivan, C. Y., Preuschoff, C.: TIMSS 2011 Assessment Frameworks. International Association for the Evaluation of Educational Achievement, The Netherlands (2009)
40. Miettinen, R.: Object of Activity and Individual Motivation. Mind, Culture and Activity. 12(1), 52--69 (2005)
41. Sannino, A.: Sustaining a Non-Dominant Activity in School: Only a Utopia? Journal of Educational Change. 9(4), 329--338 (2008)